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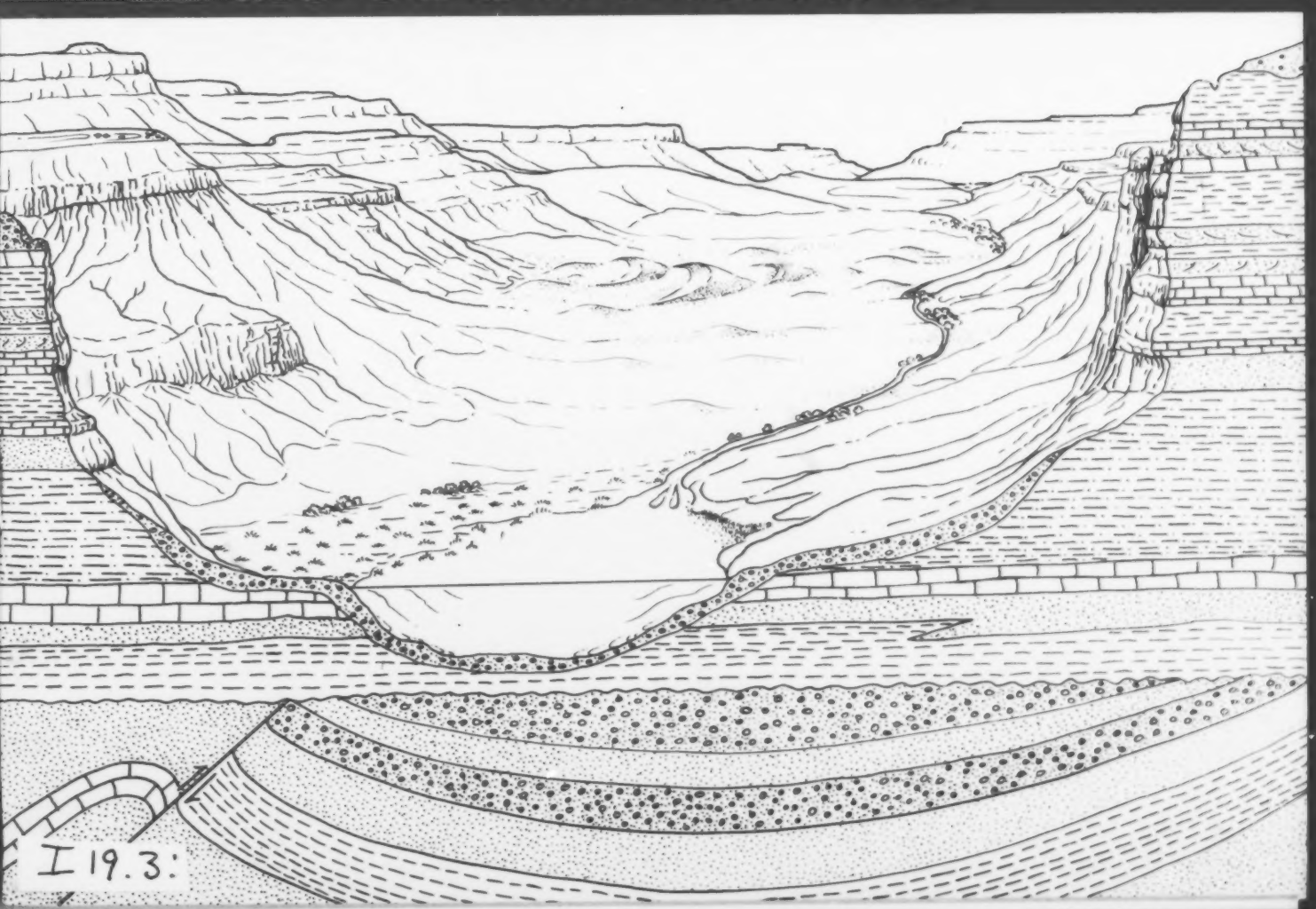

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Chapter B

Ammonites and Some Characteristic Bivalves from the Upper Cretaceous Frontier Formation, Natrona County, Wyoming

By WILLIAM A. COBBAN

A multidisciplinary approach to research studies of sedimentary rocks and their constituents and the evolution of sedimentary basins, both ancient and modern

U.S. GEOLOGICAL SURVEY BULLETIN 1917

EVOLUTION OF SEDIMENTARY BASINS—POWDER RIVER BASIN

DEPARTMENT OF THE INTERIOR
MANUEL LUJAN, JR., Secretary

U.S. GEOLOGICAL SURVEY
Dallas L. Peck, Director

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1. Localities at which fossils were collected from the Frontier Formation in Natrona County, Wyoming B6

CONVERSION FACTORS FOR SOME SI METRIC AND U.S. UNITS OF MEASURE

To convert from	To	Multiply by
Feet (ft)	Meters (m)	0.3048
Miles (mi)	Kilometers (km)	1.609
Pounds (lb)	Kilograms (kg)	0.4536
Degrees Fahrenheit (°F)	Degrees Celsius (°C)	Temp °C = (temp °F–32)/1.8

Ammonites and Some Characteristic Bivalves from the Upper Cretaceous Frontier Formation, Natrona County, Wyoming

By William A. Cobban

Abstract

The Frontier Formation in Natrona County, Wyoming, consists of two or three members of mostly shallow-water marine shale, siltstone, and sandstone. From oldest to youngest, these units are the Belle Fourche Member, the informal member of Emigrant Gap, and the Wall Creek Member. The members are separated by disconformities, and locally the Wall Creek Member rests on the Belle Fourche Member. Molluscan fossils are present in all the members, but only the Wall Creek Member contains a great variety of species. Ammonites and inoceramid bivalves are most important in zoning the Frontier Formation. Seven of the twelve established ammonite zones of middle and late Cenomanian age in the Western Interior can be recognized in the Belle Fourche Member. Two zones of middle Turonian age are present in the member of Emigrant Gap, and three zones of late Turonian age are present in the Wall Creek Member.

INTRODUCTION

The Frontier Formation in Natrona County, Wyoming (fig. 1), consists of mostly shallow-water marine sandstone, siltstone, shale, and bentonite and is 255–280 m thick. It conformably overlies the Mowry Shale and conformably underlies the Cody Shale. The Frontier consists of either two or three members, which are, from oldest to youngest, the Belle Fourche Member of early to late Cenomanian age, the informal member of Emigrant Gap (formerly known as the unnamed member) of middle Turonian age, and the Wall Creek Member of late Turonian age (fig. 2). The member of Emigrant Gap, which is developed best in the central part of Natrona County, is bounded above and below by disconformities. Where the member is absent, the Wall Creek Member rests disconformably on the Belle Fourche Member.

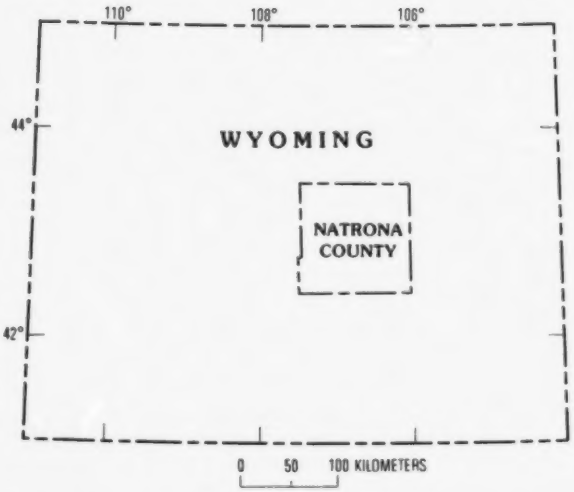

Figure 1. Map of Wyoming showing location of Natrona County.

The Frontier Formation crops out along the flanks of several anticlines, domes, and other uplifts in Natrona County (fig. 3). A map showing the Frontier outcrops in Natrona County was published by Crist and Lowry (1972, pl. 2) and reproduced in part later by Lageson (*in* Lageson and others, 1980).

Many papers have been published on the stratigraphy of the Frontier Formation of Wyoming, and several of these reports give details in Natrona County. Papers that include maps showing thicknesses of the formation, members, and submembers in Natrona County as well as

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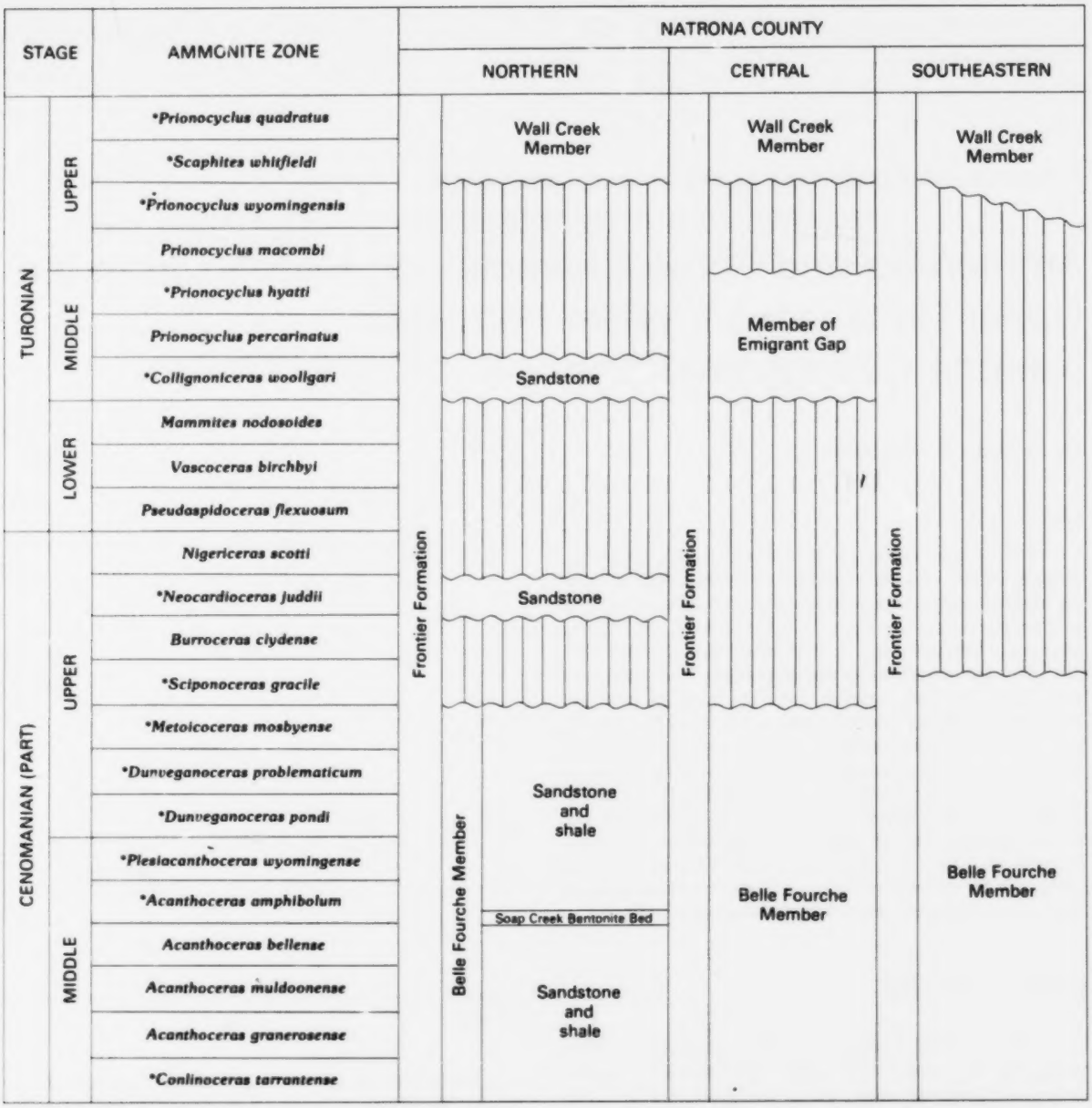

Figure 2. Ammonite zonation for the middle Cenomanian through the Turonian in the Western Interior and correlation of the Frontier Formation and members in Natrona County. Ammonite zones known to be present in Natrona County are indicated by asterisks.

correlations are given by Masters (1952), Towse (1952), Goodell (1962), Crews and others (1976), Weimer (1978), Merewether and others (1979), Merewether (1983), and Merewether and Cobban (1986a, b). Graphic sections and (or) written sections of the Frontier Formation in Natrona County have been presented by Towse (1952), Goodell (1962), Burgess (1971), Wiegand and others (1973), Merewether and Cobban (1973, 1986a, b), Merewether and others (1979), Merewether (1983), Weimer (1983), and Winn (1986). Barlow and Haun (1966) defined a "Frontier delta" that extended from western Wyoming southeastward into Natrona County. Goodell (1962) dealt with the petrology of the sandstones of the Frontier, and Bitter (1986) discussed

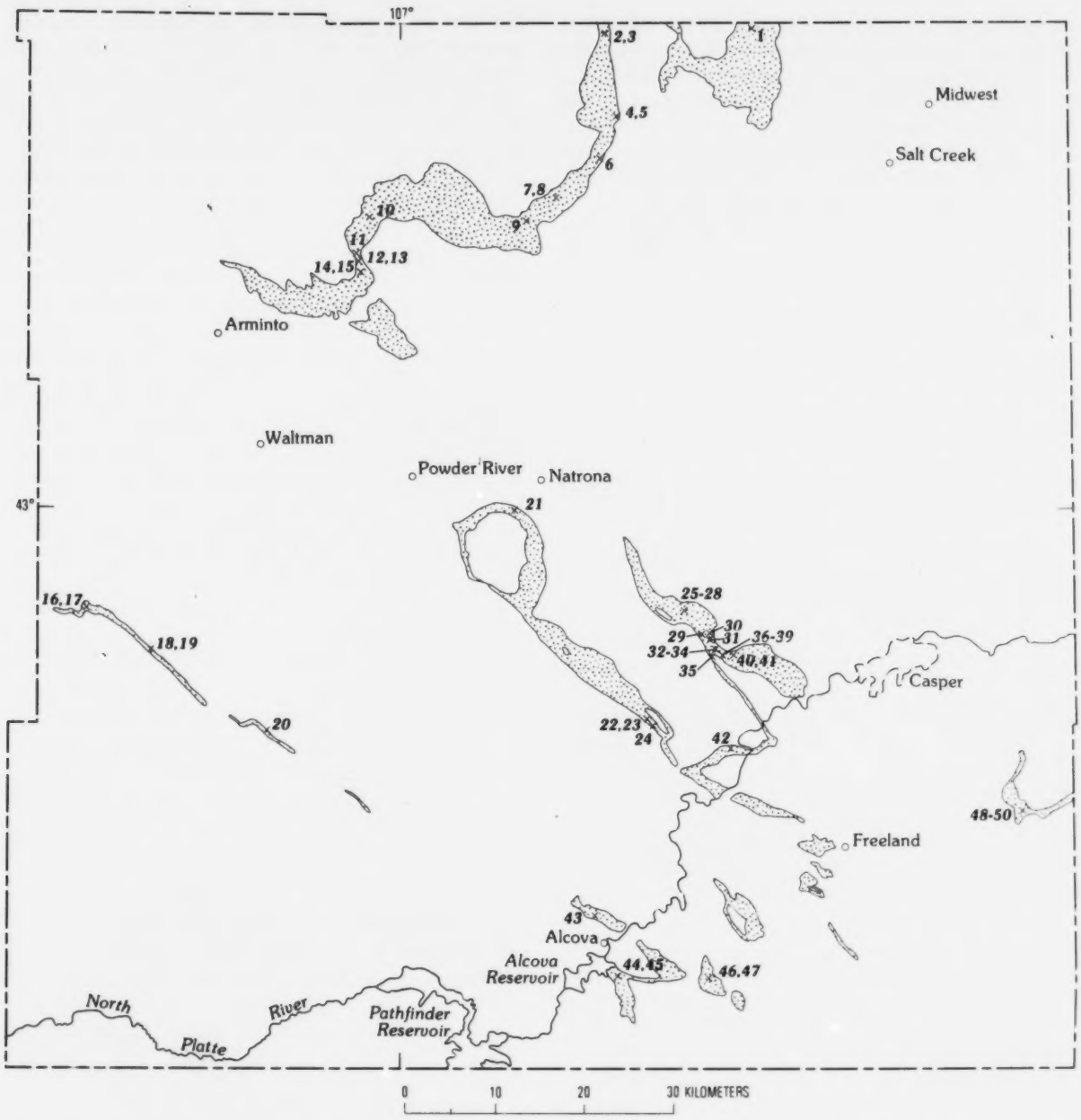

Figure 3. Localities of collections of molluscan fossils from the Frontier Formation in Natrona County referred to by number in the text and in table 1. Outcrop areas of Frontier Formation (stippled) from Love and Christiansen (1985).

the phosphatic nodules and cements in the Frontier of Natrona County.

The presence of molluscan fossils in the Frontier Formation in Wyoming has been noted in several reports, but only four mention a few generic or specific names of taxa from Natrona County (Cobban and Reeside, 1952; Masters, 1952; Merewether and others, 1979; Cobban and Kennedy, 1989). The most detailed treatment of the molluscan fossil record is by Merewether and others (1979), who illustrated seven species of ammonites from Natrona County.

The present report briefly describes most of the known species of cephalopods (chiefly ammonites) from the Frontier Formation in Natrona County as well as some of the more common bivalves. Gastropods are scarce in the Frontier, and other invertebrate fossils, such

as arthropods, are almost unknown. Fossil collections referred to in this report are either those reported in the literature or those reported here for the first time.

Fossils described in this report are kept in the National Museum of Natural History in Washington, D.C., and all have USNM catalog numbers. Plaster casts of a few of the specimens are in the reference collection of the U.S. Geological Survey at the Federal Center, Denver, Colorado. R.E. Burkholder, who recently retired from the U.S. Geological Survey, made the photographs.

LOCALITIES OF COLLECTIONS

Localities at which the specimens described or illustrated in this report were collected are shown in figure 3, which also includes other localities mentioned in the text. The U.S. Geological Survey Mesozoic locality number, names of collectors, year of collection, locality, and stratigraphic assignment are given in table 1.

MOLLUSCAN RECORD

The Frontier Formation in Natrona County contains molluscan fossils of middle and late Cenomanian age and middle and late Turonian age. In the Western Interior of the United States, 23 zones of ammonites can be recognized from the base of the middle Cenomanian to the top of the Turonian. At least 12 of these zones are present in the Frontier Formation in Natrona County.

In the discussions of the fossils and zones, a reference is given to the original description of each of the fossils, and this reference may be followed by a more accessible one that has better illustrations.

Zone of *Conlinoceras tarrantense*

This is the oldest middle Cenomanian zone of ammonites known in the Western Interior. Molluscan fossils indicative of this zone are present in the Thatcher Limestone Member of the Graneros Shale of eastern Colorado and northeastern New Mexico, in the Oak Canyon Member of the Dakota Sandstone of west-central New Mexico, in the upper part of the Belle Fourche Shale of the Black Hills region of eastern Wyoming and western South Dakota, and in the upper part of the Belle Fourche Member of the Frontier Formation of central and southeastern Wyoming. The guide ammonite, *Conlinoceras tarrantense* (Adkins, 1928, p. 241, pl. 28, fig. 3; pl. 29, fig. 1), is a stout, moderately sized species that has acanthoceratid inner whorls with umbilical, inner and outer ventrolateral tubercles, and siphonal (midventral) tubercles. Tubercles disappear on the later adult whorls, where the ornament consists of alternate long and short ribs that cross the flank and venter. For illustrations of this species, the reader is referred to Adkins (1928, pl. 28, fig. 3; pl. 29, fig. 1), where the species was described as *Metacalycoceras? tarrantense* as well as *Acanthoceras wintoni* Adkins (1928, p. 243, pl. 25, figs. 2, 3). The ammonite described as *Calycoceras (Conlinoceras) gilberti* Cobban and Scott (1972, p. 61, pl. 1; pl. 2, figs. 5–9, 13–18; pl. 3, figs. 5–7, 11; text figs. 23, 24), from the Thatcher Limestone Member of the Graneros Shale of eastern Colorado, is a closely related form that could be interpreted as a subspecies of *C. tarrantense*.

Molluscan fossils of this zone have not been collected in Natrona County. They are most certainly present in the northernmost part of the county inasmuch as *Borissiakoceras compressum* Cobban (1961, p. 747, pl. 87, figs. 19–33; pl. 89, figs. 1–9; text figs. 4a–k) and *Inoceramus eulessanus* Stephenson (1952, p. 65, pl. 44, fig. 2), fossils restricted to this zone, have been found a few hundred meters north of the Natrona-Johnson County line in the NW¼ sec. 29, T. 41 N., R. 82 W. (fig. 2, just north of loc. 2).

Zones of *Acanthoceras granerosense* and *A. muldoonense*

These zones, first recognized in the Graneros Shale above the Thatcher Limestone Member in southeastern Colorado (Cobban and Scott, 1972, table 2), are present in the upper part of the Belle Fourche Member of the Frontier Formation in Johnson County just north of Natrona County. Neither zone has been recognized in Natrona County, but future collecting may prove their presence in the upper part of the Belle Fourche Member. For illustrations of *Acanthoceras granerosense* and *A. muldoonense*, the reader is referred to Cobban and Scott (1972, pl. 2, figs. 1–4; pl. 4, figs. 1–3; pl. 5, fig. 3; pl. 6, figs. 1–3; pl. 7, figs. 1–13; pl. 11, figs. 12, 13; text figs. 27–30). Illustrations of *A. muldoonense* from Johnson County are given by Cobban (1987, pl. 3, figs. 7–34).

Zone of *Acanthoceras bellense*

This middle Cenomanian zone is known only from near the top of the Belle Fourche Shale on the west side of the Black Hills uplift in eastern Wyoming. The guide ammonite was originally described from the base of the Eagle Ford Group of east-central Texas (Adkins, 1928, p. 245, pl. 30, figs. 1, 2). The Wyoming specimens were described and illustrated by Cobban (1987, p. 5, pl. 1, figs. 18, 19; pl. 2; text fig. 5).

Zone of *Acanthoceras amphibolum*

Characteristic fossils of this zone include the ammonite *Acanthoceras amphibolum* Morrow and the bivalves *Inoceramus rutherfordi* Warren, *I. arvanus* Stephenson, and *Ostrea beloiti* Logan. These fossils are widely distributed in the Western Interior from south-central Montana to the Mexican border and from western Colorado to central Kansas.

Acanthoceras amphibolum is a moderate-size species that has inner whorls with umbilical, inner and outer ventrolateral, and siphonal tubercles. At some early growth stage siphonal tubercles may be more numerous than the ventrolateral ones, and at a later growth stage the siphonal tubercles weaken and are replaced by a low siphonal ridge. The inner and outer ventrolateral tubercles merge into outward and upward directed horns in the adult stage. The generic assignment of this species has been a problem. The species was originally described as *Acanthoceras? amphibolum* Morrow (1935, p. 470, pl. 49, figs. 1–4, 6; pl. 51, figs. 3, 4; text fig. 4), and the type lot is from the upper part of the Graneros Shale of Kansas. Since Morrow's work, the species has been assigned to *Euomphaloceras* (Stephenson, 1955, p. 63), *Paracanthoceras* (Haas, 1963, p. 18), *Plesiacanthoceras* (Haas, 1964, p. 610), and *Cunningtoniceras* (Cobban, 1987, p. 9). New investigations suggest that the species is not in the *Cunningtoniceras* lineage, and until further studies are concluded, the species *amphibolum* is probably best left in *Acanthoceras* in the broad sense.

Acanthoceras amphibolum has been definitely identified from only four localities in northwestern Natrona County (fig. 3, locs. 7, 8, 10, 15; pl. 3, figs. 6, 7; pl. 4, fig. 10). There the species was found in the upper part of the Belle Fourche Member along with *Inoceramus arvanus* Stephenson (1952, p. 65, pl. 12, figs. 6–9) and *Ostrea beloiti* Logan (1899, p. 214, pl. 25, figs. 7, 8).

Zone of *Plesiacanthoceras wyomingense*

This zone, of latest middle Cenomanian age, is present over much of the Western Interior from south-central Montana to northern New Mexico. The guide ammonite, *Plesiacanthoceras wyomingense* (Reagan) (Reagan, 1924, p. 181, pl. 19, figs. 1, 2; Cobban, 1987, p. 16, pl. 10, figs. 48–82; pls. 11–13), is a large species that attains diameters of as much as 350 mm. Earliest whorls are acanthoceratid with umbilical, inner and outer ventrolateral, and siphonal tubercles, but the last are lost early, and most of the inner whorls have depressed, smooth venters bordered by high, clavate ventrolateral tubercles (pl. 5, figs. 1, 2). As the shell enlarges, the umbilical tubercles become stronger and nodate and migrate out onto the lower part of the flank (pl. 1, fig. 11). On the last whorl of the adult, the outer ventrolateral tubercles weaken and disappear, whereas the inner ventrolateral tubercles enlarge into conspicuous horns that are directed outward and a little upward. The species has been well illustrated by Haas (1963) and Cobban (1987).

Plesiacanthoceras wyomingense was collected from the upper part of the Belle Fourche Member at five localities in Natrona County (fig. 3, locs. 16–18, 20, 45). The only other fossils found with *P. wyomingense* in Natrona County are the bivalve *Inoceramus prefragilis* Stephenson (1952, p. 64, pl. 12, figs. 10–12; pl. 13, figs. 1, 2) and the ammonites *Hamites* sp. and *Eucalycoceras templetonense* Cobban (1988a, p. 10, pl. 4, figs. 1–13; text fig. 8). Examples of the *Eucalycoceras* are shown in plates 1 and 4.

Zone of *Dunveganoceras pondi*

This is the oldest of the upper Cenomanian ammonite zones in the Western Interior. The guide ammonite, *Dunveganoceras pondi* Haas (1949, p. 22, pl. 8, figs. 1–5, 8; pl. 9, figs. 1, 3, 4; pls. 10–14; text figs. 11–13, 16, 17), came from the basal part of the Cody Shale near Greybull, Big Horn County, Wyoming. The species is large and attains a diameter of as much as 350 mm. Inner whorls have umbilical and inner and outer ventrolateral tubercles (pl. 6), whereas the outer adult whorl has an entirely different appearance. This whorl, which has a squarish cross section, is ornamented by widely spaced straight ribs of equal lengths that are accentuated at the ventrolateral shoulder and then are depressed on crossing the venter (pl. 6; pl. 7, fig. 12). Complete adults have been shown by Haas (1949, pls. 10, 11) and by Merewether and others (1979, pl. 4).

Dunveganoceras pondi has been found in brown-weathering, silty, calcareous concretions in the upper part of the Frontier Formation and basal part of the Cody Shale in the Bighorn Basin of Wyoming and in similar concretions in the upper part of the Belle Fourche Member in central Wyoming. Farther east, fragments of the species have been found in the basal bed of limestone of the Greenhorn Formation in the Black Hills area.

In Natrona County, *D. pondi* has been collected from brown-weathering, silty concretions in the upper part of the Belle Fourche Member at 11 localities. *Calycoceras* (*Proeucalycoceras*) *canitaurinum* (Haas) (Haas, 1949, p. 9, pls. 1–3; pl. 4, figs. 1, 2, 4; text figs. 1–4), a large, robust ammonite characterized by adult whorls with broad, flat ribs of alternate lengths, is a common associate. A moderately sized specimen is shown in plate 3. Other fossils found with *D. pondi* in Natrona County include the bivalves *Inoceramus prefragilis* Stephenson (1952, p. 15, pl. 19, figs. 1, 2, 4) and

Table 1. Localities at which fossils were collected from the Frontier Formation in Natrona County, Wyoming

[Localities shown by number on figure 3; USGS numbers are Mesozoic locality numbers]

Locality number	USGS number	Collector, year of collection, description of locality, and stratigraphic assignment
1	D6962	W.A. Cobban, 1969, 1970. Gierse Ranch, SW1/4 sec. 30, T. 41 N., R. 80 W. From a 2-m-thick, orange-brown-weathering, concretionary sandstone bed in upper part of Belle Fourche Member.
2	D13041	W.A. Cobban, 1989. North of Willow Creek in the SW1/4 sec. 29, T. 41 N., R. 82 W. Float from a calcareous, sandstone concretion from below the Wall Creek Member.
3	D13043	W.A. Cobban, 1989. SE1/4NE1/4SW1/4 sec. 29, T. 41 N., R. 82 W. From sandy concretions about 25 m below sandstone cliff of Wall Creek Member.
4	D9835	E.A. Merewether, 1975. NE1/4 sec. 32, T. 40 N., R. 82 W. From sandstone concretions 2.4-2.7 m above third ledge-forming sandstone below top of Frontier Formation.
5	D9833	E.A. Merewether, 1975. NW1/4 sec. 33, T. 40 N., R. 82 W. From second sandstone ledge below top of Wall Creek Member.
6	D10664	W.A. Cobban, 1978. NE1/4 sec. 18, T. 39 N., R. 82 W. From large sandstone concretions in Wall Creek Member.
7	D12959	M.C. Huff, 1988. NE1/4 sec. 34, T. 39 N., R. 83 W. From sandstone bed overlying Soap Creek Bentonite Bed of Belle Fourche Member.
8	D13042	W.A. Cobban, 1989. NE1/4NE1/4NE1/4 sec. 34, T. 39 N., R. 83 W. From sandstone bed overlying Soap Creek Bentonite Bed of Belle Fourche Member.
9	D9831	E.A. Merewether, 1975. SE1/4 sec. 5, T. 38 N., R. 83 W. From Belle Fourche Member.
10	D8471	E.A. Merewether, 1972. NE1/4 sec. 4, T. 38 N., R. 85 W. From Belle Fourche Member.
11	D8470	E.A. Merewether, 1972. NE1/4 sec. 20, T. 38 N., R. 85 W. From Belle Fourche Member.
12	D7385	W.A. Cobban, 1970. Lester Trail in the SE1/4 sec. 20, T. 38 N., R. 85 W. From gray limestone concretions in Belle Fourche Member.
13	D7383	W.A. Cobban, 1970. SW1/4 sec. 21, T. 38 N., R. 85 W. From sandstone unit in upper part of Belle Fourche Member.
14	D7382	W.A. Cobban, 1970. NW1/4 sec. 28, T. 38 N., R. 85 W. From basal 0.6 m of shale that overlies a prominent bluff-forming sandstone unit in upper part of Belle Fourche Member.
15	D12963	E.A. Merewether, 1988. SW1/4 sec. 28, T. 38 N., R. 85 W. From concretionary siltstone in Belle Fourche Member.
16	D8917	E.A. Merewether, 1973. NW1/4 sec. 19, T.34 N., R. 88 W. From upper part of Belle Fourche Member.
17	D8918	E.A. Merewether, 1973. SW1/4 sec. 19, T. 34 N., R. 88 W. From upper part of Belle Fourche Member.
18	D9324	E.A. Merewether and W.A. Cobban, 1974. Northeast of Jameson Ranch in the SE1/4 sec. 2, T. 33 N., R. 87 W. From brown and dusky-red ferruginous, silty concretions in Belle Fourche Member.
19	D9325	E.A. Merewether and W.A. Cobban, 1974. SE1/4 sec. 2, T. 33 N., R. 88 W. From coarse-grained, friable sandstone in member of Emigrant Gap.
20	D9319	W.A. Cobban, 1974. NW1/4 sec. 6, T. 32 N., R. 86 W. From dusky-red, ferruginous concretions beneath a thick, gray, bentonitic unit in Belle Fourche Member.
21	D9787	E.A. Merewether, 1975. North side of Pine Mountain in the SW1/4 sec. 18, T. 35 N., R. 83 W. From about 12 m below top of Wall Creek Member.
22	D9877	W.A. Cobban, 1976. NE1/4 sec. 34, T. 33 N., R. 82 W. From small, brown-weathering limestone concretions 7.5-9 m above coarse-grained sandstone of member of Emigrant Gap.
23	D9878	E.A. Merewether and W.A. Cobban, 1976. NE1/4 sec. 34, T. 33 N., R. 82 W. From brown-weathering limestone concretions 12 m above coarse-grained sandstone of member of Emigrant Gap.
24	D9766	E.A. Merewether, 1975. SW1/4 sec. 35, T. 33 N., R. 82 W. From float from brown-weathering limestone concretions of member of Emigrant Gap below Wall Creek Member.
25	D9749	E.A. Merewether, 1975. SW1/4 sec. 19, T. 34 N., R. 81 W. From member of Emigrant Gap.
26	D9748	E.A. Merewether, E.T. Cavanaugh, and W.A. Cobban, 1975. SW1/4 sec. 19, T. 34 N., R. 81 W. From pebbly sandstone bed in upper part of Belle Fourche Member.
27	D9747	E.A. Merewether, E.T. Cavanaugh, and W.A. Cobban, 1975. NW1/4 sec. 30, T. 34 N., R. 81 W. From Belle Fourche Member.
28	D12547	E.A. Merewether and W.A. Cobban, 1984. NE1/4 sec. 25, T. 34 N., R. 82 W. From Belle Fourche Member.
29	D9337	E.A. Merewether and W.A. Cobban, 1974. Emigrant Gap Ridge in the NW1/4 sec. 32, T. 34 N., R. 81 W. From pebbly sandstone bed in upper part of Belle Fourche Member.
30	D9359	E.T. Cavanaugh, 1975. NE1/4 sec. 32, T. 34 N., R. 81 W. From top of Wall Creek Member.
31	D9746	E.A. Merewether, E.T. Cavanaugh, and W.A. Cobban, 1975. SE1/4 sec. 32, T. 34 N., R. 81 W. From upper part of member of Emigrant Gap.
32	D9118	E.A. Merewether and W.A. Cobban, 1974. Emigrant Gap Ridge in the NE1/4 sec. 4, T. 33 N., R. 81 W. From calcareous, sandstone concretions in uppermost part of Wall Creek Member.
33	D12645	W.A. Cobban, 1985. N1/2 sec. 4, T. 33 N., R. 81 W. From upper few meters of member of Emigrant Gap.
34	D10522	E.A. Merewether, S.C. Hook, and W.A. Cobban, 1978. NW1/4 sec. 4, T. 33 N., R. 81 W. From limestone concretions in gray sandy shale unit in upper part of member of Emigrant Gap.
35	D9358	E.T. Cavanaugh, 1975. SE1/4 sec. 5, T. 33 N., R. 81 W. From top of Wall Creek Member.

Table 1. Continued

Locality number	USGS number	Collector, year of collection, description of locality, and stratigraphic assignment
36	D9333	W.A. Cobban, 1974. Emigrant Gap Ridge in the SE1/4 sec. 4, T. 33 N., R. 81 W. From very fine grained shaly sandstone in middle part of member of Emigrant Gap.
37	D9742	E.A. Merewether, E.T. Cavanaugh, and W.A. Cobban, 1975. SW1/4 sec. 3, T. 33 N., R. 81 W. From upper part of Wall Creek Member.
38	D9335	E.A. Merewether, 1974. SE1/4 sec. 4, T. 33 N., R. 81 W. From brown-weathering very fine grained sandstone concretions in a sandstone bed in the Belle Fourche Member.
39	D9365	E.T. Cavanaugh, 1975. SE1/4 sec. 4, T. 33 N., R. 81 W. From a 15-m-thick sandstone bed in the Belle Fourche Member.
40	D9116	E.A. Merewether and W.A. Cobban, 1974. SE1/4 sec. 3, T. 33 N., R. 81 W. From sandstone concretions near top of Wall Creek Member.
41	D9357	E.T. Cavanaugh, 1975. NW1/4 sec. 11, T. 33 N., R. 81 W. From Wall Creek Member.
42	D9764	E.A. Merewether, 1975. NE1/4 sec. 9, T. 32 N., R. 81 W. From top of Wall Creek Member.
43	D3117	D.L. Eicher, 1961. NW1/4 sec. 12, T. 30 N., R. 83 W. From gray limestone concretions in Belle Fourche Member 6 m below base of member of Emigrant Gap.
44	D8914	E.A. Merewether, W.J. Kennedy, and W.A. Cobban, 1973. NE1/4 sec. 31, T. 30 N., R. 82 W. From brown-weathering, sandy, limestone concretions at top of a soft sandstone bed in Belle Fourche Member.
45	D9125	E.A. Merewether and W.A. Cobban, D9125. NE1/4 sec. 31, T. 30 N., R. 82 W. From a 4.5-m-thick bed of soft sandstone that overlies a unit of dark-gray shale with several beds of bentonite in the Belle Fourche Member.
46	D11796	E.A. Merewether, 1976. NW1/4 sec. 32, T. 30 N., R. 81 W. From upper part of Wall Creek Member.
47	D11793	E.A. Merewether and W.A. Cobban, 1976. NW1/4 sec. 32, T. 30 N., R. 81 W. From a brown-weathering, sandy, limestone concretion in upper part of Belle Fourche Member.
48	D9119	E.A. Merewether and W.A. Cobban, 1974. SW1/4 sec. 36, T. 32 N., R. 78 W. From a 6-m-thick unit of carbonaceous, sandy shale and flaggy sandstone between ledge-forming sandstone units in the Wall Creek Member.
49	D9120	E.A. Merewether and W.A. Cobban, 1974. SW1/4 sec. 36, T. 32 N., R. 78 W. From basal part of a 14-m-thick, ledge-forming sandstone unit that underlies D9119 in the Wall Creek Member.
50	D9121	E.A. Merewether and W.A. Cobban, 1974. SW1/4 sec. 36, T. 32 N., R. 78 W. From a 6-m-thick, ledge-forming sandstone unit that overlies D9119 in the Wall Creek Member.

Plicatula sp. and the ammonites *Calycoceras newboldi wyomingense* Cobban (1988b, p. 5, pl. 3, fig. 5; pl. 4, figs. 2, 3; text figs. 3, 4), *Tarrantoceras flexicostatum* Cobban (1988a, p. 7, pl. 2, figs. 23–26; text fig. 5) (pl. 9, fig. 25), *Eucalycoceras templetonense* Cobban (1988a, p. 10, pl. 4; text fig. 8), *Metoicoceras praecox* Haas (1949, p. 15, pls. 5–7; text figs. 5–9), and *Hamites* sp.

Zone of *Dunveganoceras problematicum*

This zone is known only from the west side of the Powder River Basin in central and north-central Wyoming. *Dunveganoceras problematicum* Cobban (1988b, p. 9, pl. 2, figs. 4–6; pl. 3, fig. 4; pl. 8, figs. 1, 2; pls. 10–12; pl. 13, fig. 3; text figs. 8–11) is a large, moderately compressed ammonite that has very involute inner whorls with weak, closely spaced ribs and umbilical bullae and stronger inner and outer ventrolateral tubercles enclosing a sulcate venter. The outer adult whorl is much different; it is fairly evolute and has an ogival cross section and ornament of ribs only (pl. 8, fig. 3).

A subspecies, *D. problematicum natronense* Cobban (1988b, p. 11, pl. 3, fig. 4; pls. 11, 12; pl. 13, fig. 3; text figs. 10, 11), has been found in a conglomeratic sandstone in the upper part of the Belle Fourche Member at three localities in Natrona County (fig. 3, locs. 26, 29, 47). This subspecies differs from the typical form in that ribs are more numerous and tend to be of equal lengths (pl. 8, fig. 3).

Fossils found with *D. problematicum natronense* in Natrona County are *Inoceramus prefragilis* Stephenson, *Moremanoceras costatum* Cobban, Hook, and Kennedy (1989, p. 19, figs. 19, 64A–D, G, H), *Calycoceras* aff. *canitaurinum* (Haas) (Cobban, 1988b, p. 7, pl. 5; pl. 6, figs. 1, 2), *Neocardioceras uptonense* Cobban (1988a, p. 20, pl. 10, figs. 36–70; text fig. 17), *Metoicoceras frontierense* Cobban (1988b, p. 13, pl. 3, figs. 1–3; pl. 13, figs. 1, 2; pl. 14; text fig. 12) (pl. 3, figs. 8, 9; pl. 9, figs. 26, 27), and *Hamites* sp.

Zone of *Metoicoceras mosbyense*

Molluscan fossils representing this middle upper Cenomanian zone are widely distributed over the Western Interior from northern Montana to southwestern New Mexico. *Metoicoceras mosbyense* is a fairly large, compressed ammonite that has very involute inner whorls ornamented by primary and secondary ribs with

umbilical bullae and inner and outer ventrolateral tubercles (pl. 2, figs. 1–3). Adult whorls are more evolute and have broad, flattened ribs and no tubercles (pl. 2, figs. 8, 9). The species was first described from the Mosby Sandstone Member of the Belle Fourche Shale of east-central Montana (Cobban, 1953a, p. 48, pl. 6, figs. 1–14; pl. 7, figs. 1–3).

Metoicoceras mosbyense has been collected from near the top of the Belle Fourche Member of the Frontier Formation at 26 localities in Natrona County. Most fossils are from concretions of calcareous siltstone and from beds of sandstone. Fossils found with *M. mosbyense* are the bivalves *Inoceramus pictus* Sowerby (1829, p. 215, pl. 604, fig. 1) (pl. 1, fig. 3), *I. ginterensis* Pergament (1966, p. 50, pl. 25, fig. 5; pl. 26, figs. 1, 2; pl. 27, figs. 1, 2; pl. 28, figs. 1, 2; pl. 29, fig. 1) (pl. 10, figs. 10–12), and *Pycnodonte* aff. *kellumi* (Jones) (Jones, 1938, p. 107, pl. 3, figs. 3–5) (pl. 3, figs. 1–4), and the ammonites *Calycoceras obrieni* Young (1957, p. 1171, pl. 150, figs. 1–4; text figs. 1f, h), *Dunveganoceras conditum* Haas (1951, p. 5, figs. 2–9), *D. albertense* (Warren) (Warren, 1930, p. 21, pl. 1, figs. 1, 2), *Neocardioceras minutum* Cobban (Cobban, 1988a, p. 23, pl. 10, figs. 1–35; text fig. 20), and *Hamites salebrosus* Cobban, Hook, and Kennedy (1989, p. 57, fig. 95BB, EE–II) (pl. 3, figs. 12, 13). *Dunveganoceras conditum* is a large, evolute ammonite that has inner whorls with umbilical bullae and conspicuous inner and outer ventrolateral tubercles (pl. 8, figs. 1, 2) and outer adult whorl with rounded section and prominent ribs of equal lengths crossing the flanks and venter (pl. 11). *Dunveganoceras albertense*, which seems to occur a little below *D. conditum*,, has similar inner whorls, but the outer adult whorl has an ogival section and sparser ribs.

Zone of *Sciponoceras gracile*

Rocks that represent this upper Cenomanian zone are known in Natrona County only near the southern edge of the county (fig. 3, loc. 43). Elsewhere in the county, rocks of this age apparently were removed before deposition of the member of Emigrant Gap or the Wall Creek Member, both of which have disconformable basal contacts (Merewether and Cobban, 1986a).

The guide fossil, *Sciponoceras gracile* (Shumard) (Shumard, 1860, p. 596), is a small, straight ammonite that has a subcircular cross section, low angle of taper, and ornament of weak ventral ribs and fewer but stronger constrictions (pl. 9, figs. 4–15). The species has a wide geographic distribution that extends from Montana to southwestern New Mexico and to eastern Texas and western Europe.

In the southern part of Natrona County, near Alcova, limestone concretions in the Belle Fourche Member 6 m below the disconformable base of the Wall Creek Member contain *S. gracile* (pl. 9, figs. 4–15) and the bivalves *Inoceramus ginterensis* Pergament (pl. 10, fig. 10) and *Phelopteria* sp. and the ammonites *Placenticeras* (*Karamaites*) *cumminsi* Cragin (1893, p. 237), *Borissiakoceras orbiculatum* Stephenson (1955, p. 64, pl. 6, figs. 1–4) (pl. 9, figs. 23, 24), *Euomphaloceras septemseriatum* (Cragin) (Cragin, 1893, p. 240; Cobban and Scott, 1972, p. 72, pl. 12, figs. 5–27), and *Allocrioceras annulatum* (Shumard) (Shumard, 1860, p. 595) (pl. 9, figs. 1–3).

Zone of *Burroceras clydense*

This upper Cenomanian zone is known only in southwestern New Mexico. The guide fossil, *Burroceras clydense*, and associated ammonites were recently described by Cobban and others (1989).

Zone of *Neocardioceras juddii*

The ornate ammonite *Neocardioceras juddii* (Barrois and de Guerne) (Barrois and de Guerne, 1878, p. 46, pl. 1, figs. 1a, b, 2a, b), originally described from France, is widely distributed in the Western Interior. This fairly small, moderately evolute species has numerous, narrow primary and secondary ribs that cross the venter and bear small inner and outer ventrolateral and siphonal tubercles (Cobban and others, 1989, p. 31, figs. 33, 75F–DD, II–MM). The longer (primary) ribs arise from thin umbilical bullae.

The zone of *N. juddii* is present in a thin sandy unit in the Frontier Formation below the Wall Creek Member at two localities in northern Natrona County (fig. 3, locs. 3, 4). This sandy unit contains some coarse-grained sandstone; small, black-coated chert pebbles; and light-gray to yellow or orange weathering, tabular calcareous concretions with cone-in-cone structure. The known fauna consists of solitary corals; the bivalves *Phelopteria* sp. and *Inoceramus* cf. *tenuistriatus* Nagao and Matsumoto (1939, p. 272, pl. 24, fig. 8; pl. 26, figs. 1–4); small gastropods; and the ammonites *Burroceras irregulare* Cobban, Hook, and Kennedy (1989, p. 38, figs. 39, 80S–V), *Euomphaloceras costatum* Cobban, Hook, and Kennedy (1989, p. 37, figs. 37, 77S–EE, 78A–H), *Sciponoceras gracile* (Shumard), and *Yezoites* sp. (Kennedy, 1988, pl. 24).

Zones of *Nigericeras scotti*, *Pseudaspidoceras flexuosum*, *Vascoceras birchbyi*, and *Mammites nodosoides*

These zones of latest Cenomanian and early Turonian age seem to be absent in Natrona County owing to erosion at the disconformities at either the base of the

member of Emigrant Gap or the base of the Wall Creek Member (Merewether and Cobban, 1986a). *Nigericeras scotti* Cobban (1971, p. 18, pl. 9, figs. 1–4; pl. 18, figs. 1–9; text figs. 15–17), of latest Cenomanian age, is known only from southeastern Colorado, northeastern New Mexico, and possibly southwestern New Mexico. *Pseudaspidoceras flexuosum* Powell (1963, p. 318, pl. 32, figs. 1, 9, 10; text figs. 2a–c, f, g), originally described from Trans-Pecos Texas, has been found in southwestern New Mexico, eastern Arizona, and southeastern Colorado but not farther north. *Vascoceras birchbyi* Cobban and Scott (1972, p. 85, pl. 22; pl. 23, figs. 1–13; pl. 24, figs. 1–12; pl. 25; pl. 26, figs. 5–8, 11, 12; pl. 27, figs. 1–6; text figs. 43–47) is known from central Kansas, eastern Colorado, central Utah, and northeastern and southwestern New Mexico. *Mammites nodosoides* (Schlüter) (Schlüter, 1871, p. 19, pl. 8, figs. 1–4; Cobban and others, 1989, p. 41, figs. 42, 90D–H, M, N) has been found at many localities from southern New Mexico to southwestern Wyoming, but not farther north.

Zone of *Collignoniceras woollgari*

Collignoniceras woollgari (Mantell) is an ornate, somewhat evolute ammonite characterized by narrow, forwardly slanting ribs that bear umbilical bullae, inner and outer ventrolateral tubercles, and elongated siphonal tubercles (pl. 5, figs. 6–13). Most specimens are small, although the species is known to attain a fairly large size. *Collignoniceras woollgari* (Mantell) was originally described from the Middle Chalk of England (Mantell, 1822, p. 197, pl. 21, fig. 16; pl. 22, fig. 7). The species has a wide geographic distribution in rocks of early middle Turonian age; specimens have been recorded from Europe, Texas, the Western Interior of the United States and Canada, California, Oregon, Japan, and northern Australia.

Two chronologic subspecies have been recognized in the Western Interior (Cobban and Hook, 1979). The older, *C. woollgari woollgari*, has in the adult stage secondary ribs as well as more siphonal tubercles than ventrolateral ones. The younger subspecies, *C. woollgari regulare* (Haas) (Haas, 1946, p. 154, pl. 16, figs. 1–17; text figs. 10–12, 59–74, 78, 80, 81, 83), has more uniformly sized ribs and equal numbers of ventrolateral and siphonal tubercles.

Both forms of *C. woollgari* have been collected from the member of Emigrant Gap of the Frontier Formation at 23 localities in an east-west belt across central Natrona County. Specimens occur either in fairly coarse, crossbedded sandstone or in silty, calcareous concretions, where they may be abundant (pl. 5, fig. 9). Other molluscan fossils are not common but include the bivalves *Inoceramus fragilis* Hall and Meek (1856, p. 388, pl. 2, figs. 6a, b; Cobban, 1983, p. 3, pl. 1, fig. 2) and *I. hercynicus* Petrascheck (1903, p. 156, pl. 8, figs. 1–3; text fig. 1) (pl. 1, fig. 6); the ammonites *Tragodesmoceras* sp., *Baculites yokoyamai* Tokunaga and Shimizu (1926, p. 195, pl. 22, figs. 5a, b; pl. 26, fig. 11) (pl. 9, figs. 16–22), and *Allocrioceras billinghursti* Klinger (1976, p. 32, pl. 9, figs. 2a, b; text fig. 7b; Cobban and Kennedy, 1989, p. 173, figs. 1a–f); and the belemnite *Actinocamax* sp. (Jeletzky, 1961).

A single specimen of *C. woollgari* was recently collected from a calcareous, sandy concretion from an unnamed unit below the Wall Creek Member at the northern edge of Natrona County (fig. 3, loc. 2).

Zone of *Prionocyclus percarinatus*

Prionocyclus is an ornate, somewhat evolute ammonite that has a finely notched keel, hence, the name *prionos* (Greek, saw) and *kyklos* (Greek, circle) or circular saw. The various species of *Prionocyclus* are important in the zonation of the middle and upper Turonian (fig. 1).

Prionocyclus percarinatus (Hall and Meek), originally described as *Ammonites percarinatus* Hall and Meek (1856, p. 396, pl. 4, figs. 2a, b), is a common species in the Carlile Shale in an east-west trending belt that extends from the southern end of the Black Hills to southwestern Minnesota. The types and other specimens were illustrated by Cobban (1983, pl. 5, figs. 26–37).

Prionocyclus percarinatus has not been found in Natrona County.

Zone of *Prionocyclus hyatti*

Prionocyclus hyatti (Stanton), of latest middle Turonian age, has both primary ribs with umbilical bullae and inner and outer ventrolateral tubercles, and shorter and weaker secondary ribs with only ventrolateral tubercles (pl. 4, figs. 8, 9; pl. 5, figs. 3–5). The species was first described as *Prionotropis hyatti* Stanton (1893, p. 176, pl. 42, figs. 5–8) from rocks now assigned to the Codell Sandstone Member of the Carlile Shale of south-central Colorado. *Prionocyclus hyatti* has been found in silty, calcareous concretions in the member of Emigrant Gap at only three localities in the Casper area (fig. 3, locs. 22–24). Associated fossils are *Inoceramus howelli* White (1876, p. 114; 1879, p. 284, pl. 4, figs. 1a–c) (pl. 10, fig. 9) and the ammonites *Placenticeras* (*Placenticeras*) *pseudoplacenta* Hyatt (1903, p. 216) and *Pteroscaphites* n. sp.

Zone of *Prionocyclus macombi*

This zone of early late Turonian age is unknown in Natrona County owing to the erosional contact at the

base of the Wall Creek Member (fig. 1). The guide ammonite, *Prionocyclus macombi* Meek (1876a, p. 132, pl. 2, figs. 3a–d; Stanton, 1893, p. 172, pl. 41, figs. 1–5), is a slender species that has densely ribbed early whorls and almost smooth later whorls. The species is abundant in the basal beds of the Juana Lopez Member of the Mancos Shale in southwestern Colorado and northwestern New Mexico. *Prionocyclus macombi* has been found in the basal part of the Wall Creek Member in Carbon County south of Natrona County.

Zone of *Prionocyclus wyomingensis*

Prionocyclus wyomingensis Meek (1876b, p. 452) is a robust, moderately evolute, keeled species that has narrow ribs of irregular height of which the higher or stronger ones bear umbilical tubercles (double occasionally) as well as inner and outer ventrolateral tubercles of which the outer ones are very weak. The species was not illustrated by Meek, but White (1883, pl. 15, fig. 1a–e) showed good sketches of the types. White's illustrations have been reproduced in several publications (for example, Stanton, 1893, pl. 40; Grabau and Shimer, 1910, figs. 1510a–d). Molluscan fossils usually found with *P. wyomingensis* are *Inoceramus dimidius* White (1877, p. 181, pl. 16, figs. 2a–d; Stanton, 1893, p. 78, pl. 10, figs. 5, 6), *Lopha lugubris* (Conrad) (Conrad, 1857, p. 156, pl. 10, figs. 5a, b; Stanton, 1893, pl. 4), and *Scaphites warreni* Meek and Hayden (1860, p. 177; Cobban, 1951, pl. 3, figs. 8–21).

Prionocyclus wyomingensis has not been found in Natrona County, but the bivalve *Lopha lugubris* (pl. 2, figs. 5–7) was discovered in the basal part of the Wall Creek Member of the Frontier Formation in the southeastern part of the county (fig. 3, loc. 49).

Zone of *Scaphites whitfieldi*

The ammonite *Scaphites whitfieldi* Cobban (1951, p. 24, pl. 4, figs. 30–40; pl. 5, figs. 2–4 only) is typical of the scaphites in which the adult body chamber becomes partly straightened and uncoiled. Ornament of the body chamber consists of closely and evenly spaced primary and secondary ribs.

Scaphites whitfieldi is widely distributed in the Western Interior from southern Montana to southern New Mexico. Associated fossils are usually *Inoceramus perplexus* Whitfield (1880, p. 392, pl. 8, fig. 3; pl. 10, figs. 4, 5) (pl. 1, fig. 8; pl. 10, fig. 1), *Prionocyclus novimexicanus* (Marcou) (Marcou, 1858, p. 36, pl. 1, figs. 2, 2a), *Prionocyclus wyomingensis* var. *elegans* of Haas (1946, p. 200, pl. 19, figs. 1–7, 11–14; pl. 20, fig. 4; pl. 21, figs. 1–3, 5; pl. 22, figs. 1, 2; text figs. 98–104), a[n] *Carota*? cf. *biplicata* Stephenson (a gastropod identified by N.F. Sohl). The occurrence of *I. perplexus* in the Wall Creek Member at 12 localities in northern and southeastern Natrona County suggests that the zone of *S. whitfieldi* is probably present in the lower part of the member over much of the county. *Prionocyclus novimexicanus* was found with *I. perplexus* at seven of these localities. Other fossils are scarce but include an occasional cardiinid bivalve such as *Pleuriocardia* sp. (pl. 3, fig. 5).

Zone of *Prionocyclus quadratus*

The ammonite, *Prionocyclus quadratus* Cobban (1953b, p. 354, pl. 48, figs. 1–8), is rather uncommon in the Western Interior. Many specimens referred to it are probably *P. germari* (Reuss) (Reuss, 1845, p. 22, pl. 7, figs. 10a–c). *Prionocyclus quadratus* has inner whorls that have closely spaced primary and secondary ribs of which the primary ones bear umbilical and inner and outer ventrolateral tubercles. Adult whorls have stout, squarish whorl sections and ornament of primary ribs with umbilical and inner ventrolateral tubercles as well as an incipient midflank tubercle. *Prionocyclus germari* has more slender whorls and lacks the incipient midflank tubercle.

The zone of *P. quadratus*, of latest Turonian age, is the most fossiliferous part of the Frontier Formation in Natrona County. Collections were made from the Wall Creek Member at 32 localities scattered over much of the county. Small echinoids were found at three places (fig. 3, locs. 32, 37, 41). The largest collection of molluscan fossils came from calcareous sandstone concretions in the uppermost sandstone unit of the Wall Creek Member at the Emigrant Gap anticline (fig. 3, loc. 32). Here the following species were collected:

Bivalves
- *Nucula* sp.
- *Nuculana* sp.
- *Solemya obscura* Stanton
- *Modiolus* sp.
- *Pinna* sp.
- *Phelopteria* sp.
- *Inoceramus incertus* Jimbo
- *I. cuvieriformis* Pergament
- *Rhynchostreon* sp.
- *Syncyclonema* sp.
- *Crassatella hendricksoni* Henderson
- *Pleuriocardia* (*Dochmocardia*) aff. *pauperculum* (Meek)
- *Tellina*? *isonema* Meek
- *Cymbophora utahensis* (Meek)
- *C. emmonsi* (Meek)
- *Laternula* sp.
- *Parapholas sphenoideus* White

Gastropods

Gyrodes depressa Meek
G. conradi Meek
Euspira? sp.
Anisomyon apicalis Sidwell

Ammonites

Placenticeras (*P.*) *pseudoplacenta* Hyatt (pl. 4, figs. 13, 14)
Prionocyclus germari (Reuss) (pl. 7, figs. 1–11)
Baculites yokoyamai Tokunaga and Shimizu
B. aff. *sweetgrassensis* Cobban (pl. 3, figs. 10, 11)
Eubostrychoceras matsumotoi Cobban (pl. 9, figs. 28–35)
Scaphites corvensis Cobban (pl. 4, figs. 3–7)

Nautiloid

Eutrephoceras sp. (pl. 4, figs. 11, 12)

A variety of inoceramid species is present in the Wall Creek Member. The most abundant species, *Inoceramus incertus* Jimbo (1894, p. 43, pl. 8, fig. 7; Scott and others, 1986, fig. 6g), is a well-ornamented form that has two orders of concentric folds (pl. 10, figs. 2–5). Another abundant species, *I. longealatus* Tröger (1967, p. 95, pl. 10, fig. 2; Scott and others, 1986, figs. a-e, i), has a long, straight hingeline that forms part of a conspicuous wing (pl. 10, figs. 6, 7). Other species include *I. apicalis* Woods (1912, p. 319, pl. 53, figs. 4–6) (pl. 1, figs. 1, 2), *I. cuvieriformis* Pergament (1971, p. 52, pl. 6, figs. 1, 2; pl. 7, fig. 1) (pl. 10, fig. 8), and other forms (pl. 1, fig. 9).

Ammonites are fairly common in the Wall Creek Member, and illustrations of several species are shown in plates 3, 4, 7, and 9.

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PLATES 1–11

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PLATE 1

[All figures natural size]

Figures 1, 2. *Inoceramus* cf. *apicalis* Woods (p. B11).
USNM 443794, from the Wall Creek Member of the Frontier Formation at locality D9764 (text fig. 3, loc. 42).

3. *Inoceramus pictus* Sowerby (p. B8).
USNM 443795, from the Belle Fourche Member of the Frontier Formation at locality D6962 (text fig. 3, loc. 1).

4, 5. *Rhynchostreon* sp.
USNM 443796, from the Belle Fourche Member at locality D9335 (text fig. 3, loc. 38).

6. *Inoceramus hercynicus* Petrascheck (p. B9).
Latex cast of USNM 443797, from the member of Emigrant Gap of the Frontier Formation at locality D9749 (text fig. 3, loc. 25).

7. *Eucalycoceras templetonense* Cobban (p. B5).
USNM 443798, from the Belle Fourche Member at locality D8918 (text fig. 3, loc. 17).

8. *Inoceramus perplexus* Whitfield (p. B10).
USNM 443799, from the Wall Creek Member at locality D9121 (text fig. 3, loc. 50).

9. *Inoceramus* sp. (p. B11).
Latex cast of USNM 443800, from the Wall Creek Member at locality D11796 (text fig. 3, loc. 46).

10, 11. *Plesiacanthoceras wyomingense* (Reagan) (p. B5).
USNM 443801, from the Belle Fourche Member at locality D9324 (text fig. 3, loc. 18).

FOSSILS FROM THE FRONTIER FORMATION

PLATE 2

[All figures natural size]

Figures 1–3, 8, 9. *Metoicoceras mosbyense* Cobban (p. B8).

1–3. USNM 443802, from the Belle Fourche Member of the Frontier Formation at locality D7383 (text fig. 3, loc. 13).

8, 9. USNM 443803, from the Belle Fourche Member at locality D8470 (text fig. 3, loc. 11).

4. *Rhynchostreon* sp.

USNM 443804, from the Belle Fourche Member at locality D9365 (text fig. 3, loc. 39).

5–7. *Lopha lugubris* (Conrad) (p. B10).

5. USNM 443805, from the Wall Creek Member of the Frontier Formation at locality D9120 (text fig. 3, loc. 49).

6, 7. USNM 443806, from the Wall Creek Member at locality D9120 (text fig. 3, loc. 49)

FOSSILS FROM THE FRONTIER FORMATION

PLATE 3

[All figures natural size]

Figures 1–4. *Pycnodonte* aff. *kellumi* (Jones) (p. B8).

1, 2. USNM 443807, from the Belle Fourche Member of the Frontier Formation at locality D7382 (text fig. 3, loc. 14).

3, 4. USNM 443808, from the Belle Fourche Member at locality D7385 (text fig. 3, loc. 12).

5. *Pleuriocardia* sp. (p. B10).
Latex cast of USNM 443809, from the Wall Creek Member of the Frontier Formation at locality D9119 (text fig. 3, loc. 48).

6, 7. *Acanthoceras amphibolum* Morrow (p. B5).
USNM 443810, from the Belle Fourche Member at locality D8471 (text fig. 3, loc. 10).

8, 9. *Metoicoceras frontierense* Cobban (p. B7).
Holotype USNM 376927, from the Belle Fourche Member at locality 22809 in the NE¼ sec. 1, T. 43 N, R. 83 W., Johnson County, Wyo.

10, 11. *Baculites* aff. *sweetgrassensis* Cobban (p. B11).
USNM 443811, from the Wall Creek Member at locality D9116 (text fig. 3, loc. 40).

12, 13. *Hamites salebrosus* Cobban, Hook, and Kennedy (p. B8).
USNM 443812, from the Belle Fourche Member at locality D6962 (text fig. 3, loc. 1).

14, 15. *Calycoceras canitaurinum* (Haas) (p. B5).
USNM 443813, from the Belle Fourche Member at locality D8914 (text fig. 3, loc. 44).

FOSSILS FROM THE FRONTIER FORMATION

PLATE 4

[All figures natural size]

Figures 1, 2. *Eucalycoceras templetonense* Cobban (p. B5).
USNM 443814, from the Belle Fourche Member of the Frontier Formation at locality D12547 (text fig. 3, loc. 28).

3–7. *Scaphites corvensis* Cobban (p. B11).
3–5. USNM 443815, from the Wall Creek Member of the Frontier Formation at locality D9118 (text fig. 3, loc. 32).
6, 7. USNM 443816, from the Wall Creek Member at locality D9358 (text fig. 3, loc. 35).

8, 9. *Prionocyclus hyatti* (Stanton) (p. B9).
USNM 443818, from the member of Emigrant Gap of the Frontier Formation at locality D9766 (text fig. 3, loc. 24).

10. *Acanthoceras amphibolum* Morrow (p. B5).
USNM 443817, from the Belle Fourche Member at locality D8471 (text fig. 3, loc. 10).

11, 12. *Eutrephoceras* sp. (p. B11).
USNM 443819, from the Wall Creek Member at locality D9116 (text fig. 3, loc. 40).

13, 14. *Placenticeras* (*P.*) *pseudoplacenta* Hyatt (p. B11).
USNM 443820, from the Wall Creek Member at locality D9358 (text fig. 3, loc. 35).

FOSSILS FROM THE FRONTIER FORMATION

PLATE 5

[All figures natural size]

Figures 1, 2. *Plesiacanthoceras wyomingense* (Reagan) (p. B5).
USNM 443821, from the Belle Fourche Member of the Frontier Formation at locality D9324 (text fig. 3, loc. 18).

3–5. *Prionocyclus hyatti* (Stanton) (p. B9).
USNM 443822, from the member of Emigrant Gap of the Frontier Formation at locality D9877 (text fig. 3, loc. 22).

6–13. *Collignoniceras woollgari* (Mantell) (p. B9).

6. USNM 443823, from the member of Emigrant Gap at locality D9746 (text fig. 3, loc. 31).
7, 8. USNM 443824, from the member of Emigrant Gap at locality D10522 (text fig. 3, loc. 34).
9. USNM 443825, from the member of Emigrant Gap at locality D9746 (text fig. 3, loc. 31).
10. USNM 443826, from the member of Emigrant Gap at locality D9325 (text fig. 3, loc. 19).
11. Latex cast of USNM 443827, from the member of Emigrant Gap at locality D9333 (text fig. 3, loc. 36).
12, 13. USNM 443828, from the member of Emigrant Gap at locality D12645 (text fig. 3, loc. 33).

FOSSILS FROM THE FRONTIER FORMATION

PLATE 6

[Figure natural size]

Dunveganoceras pondi Haas (p. B5)

USNM 443829, from the Belle Fourche Member of the Frontier Formation at locality D9747 (text fig. 3, loc. 27). See plate 7, figure 12, for another view.

DUNVEGANOCERAS PONDI

PLATE 7

[All figures natural size]

Figures 1–11. *Prionocyclus germari* (Reuss) (p. B11).
USNM 443830–443835, from the Wall Creek Member of the Frontier Formation at locality D9118 (text fig. 3, loc. 32). Figure 7 is a latex cast.

12. *Dunveganoceras pondi* Haas (p. B5).
USNM 443829, from the Belle Fourche Member of the Frontier Formation at locality D9747 (text fig. 3, loc. 27). See plate 6 for lateral view.

PRIONOCYCLUS AND *DUNVEGANOCERAS*

PLATE 8

[All figures natural size]

Figures 1, 2. *Dunveganoceras condinum* Haas (p. B8).
USNM 443836, from the Belle Fourche Member of the Frontier Formation at locality D8470 (text fig. 3, loc. 11).

3. *Dunveganoceras problematicum natronense* Cobban (p. B7).
Holotype USNM 376921, from the Belle Fourche Member at locality D9337 (text fig. 3, loc. 29).

DUNVEGANOCERAS

PLATE 9

[All figures natural size]

Figures 1–3. *Allocrioceras annulatum* (Shumard) (p. B8).
USNM 443837, from the Belle Fourche Member of the Frontier Formation at locality D3117 (text fig. 3, loc. 43).

4–15. *Sciponoceras gracile* (Shumard) (p. B8).
From the Belle Fourche Member at locality D3117 (text fig. 3, loc. 43).

4–6. USNM 443838.

7–9. USNM 443839.

10–12. USNM 443840.

13–15. USNM 443841.

16–22. *Baculites yokoyamai* Tokunaga and Shimizu (p. B9).

16–18. USNM 443842, from the Wall Creek Member of the Frontier Formation at locality D9118 (text fig. 3, loc. 32).

19, 20. USNM 443843, from the Wall Creek Member at locality D9742 (text fig. 3, loc. 37).

21, 22. USNM 443844, from the Wall Creek Member at locality D9118 (text fig. 3, loc. 32). Specimen has a complete adult aperture.

23, 24. *Borissiakoceras orbiculatum* Stephenson (p. B8).
USNM 443845, from the Belle Fourche Member at locality D3117 (text fig. 3, loc. 43).

25. *Tarrantoceras flexicostatum* Cobban (p. B7).
USNM 443846, from the Belle Fourche Member at locality D8714 (text fig. 3, loc. 44).

26, 27. *Metoicoceras frontierense* Cobban (p. B7).
USNM 443847, from the Belle Fourche Member at locality D9337 (text fig. 3, loc. 29).

28–35. *Eubostrychoceras matsumotoi* Cobban (p. B11).

28, 29. Paratype USNM 395816, from the Wall Creek Member at locality D9118 (text fig. 3, loc. 32).

30–33. Paratype USNM 395810, from the Wall Creek Member at locality D9118 (text fig. 3, loc. 32).

34, 35. Holotype USNM 395808, from the Wall Creek Member at locality D9359 (text fig. 3, loc. 30).

FOSSILS FROM THE FRONTIER FORMATION

PLATE 10

[All figures natural size]

Figure 1. *Inoceramus perplexus* Whitfield (p. B10).
USNM 443848, from the Wall Creek Member of the Frontier Formation at locality D9833 (text fig. 3, loc. 5).

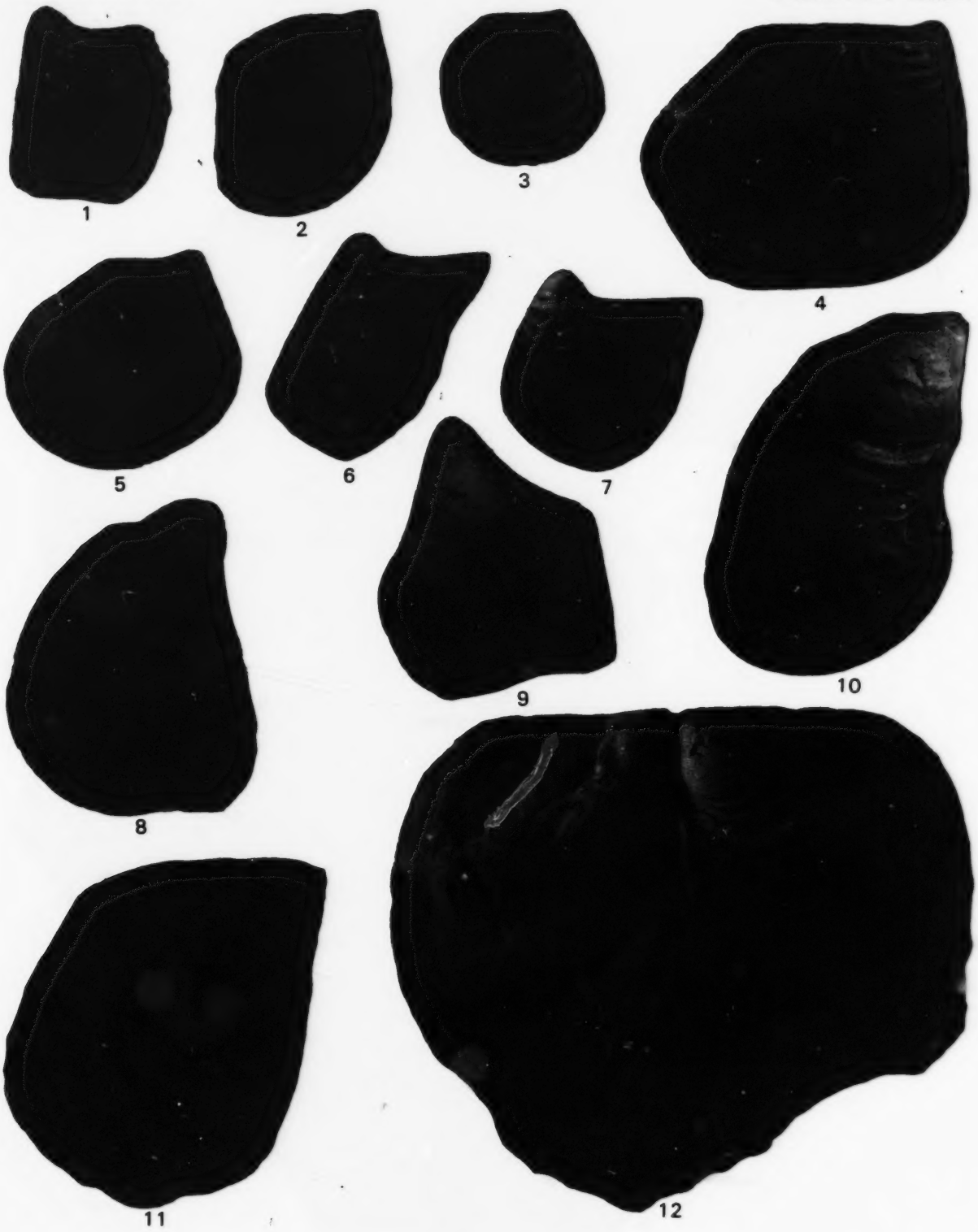
2–5. *Inoceramus incertus* Jimbo (p. B11).
From the Wall Creek Member at locality D9118 (text fig. 3, loc. 32).
2. USNM 443849.
3. USNM 443850.
4. USNM 443851.
5. USNM 443852.

6, 7. *Inoceramus longealatus* Troger (p. B9, B11)
6. USNM 443853, from the Wall Creek Member at locality D9787 (text fig. 3, loc. 21).
7. USNM 443854, from the Wall Creek Member at locality D9116 (text fig. 3, loc. 40).

8. *Inoceramus cuvieriformis* Pergament (p. B11)
USNM 443855, from the Wall Creek Member at locality D9116 (text fig. 3, loc. 40).

9. *Inoceramus howelli* White (p. B9).
USNM 443856, from the member of Emigrant Gap of the Frontier Formation at locality D9878 (text fig. 3, loc. 23).

10–12. *Inoceramus ginterensis* Pergament (p. B8).
10. USNM 443857, from the Belle Fourche Member of the Frontier Formation at locality D3117 (text fig. 3, loc. 43).
11. USNM 443858, from the Belle Fourche Member at locality D8470 (text fig. 3, loc. 11).
12. USNM 443859, from the Belle Fourche Member at locality D6962 (text fig. 3, loc. 1).



INOCERAMUS

PLATE 11

[Figure natural size]

Dunveganoceras conditum Haas (p. B8).
USNM 443860, from the Belle Fourche Member of the Frontier Formation at locality D9831 (text fig. 3, loc. 9).

DUNVEGANOCERAS

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